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Study of Optical and Structural Properties of β-$(Al_xGa_{1-x})_2O_3$ Thin Films Grown by Spray Pyrolysis Technique

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Abstract. The work demonstrates the synthesis of thin films of β-$(Al_xGa_{1-x})_2O_3$ by spray pyrolysis method. Temperature conditions for sol synthesis are determined to obtain thin films with a specified content of aluminum. The films are studied by scanning electron microscopy, energy-dispersive X-ray spectroscopy and optical spectroscopy. The aluminum content in the fabricated β-$(Al_xGa_{1-x})_2O_3$ films is about 3.6 at.%. The optical band gap of the films is determined as 5.0 eV.

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REFERENCES

[1] S.J. Pearton, J. Yang, P.H. Cary, F. Ren, J. Kim, M.J. Tadjer, M.A. Mastro, A Review of Ga_2O_3 Materials, Processing, and Devices, *Applied Physics Reviews*, 2018, vol. 5, no. 1, art. no. 011301.
[2] Z. Galazka, β-Ga_2O_3 for Wide-Bandgap Electronics and Optoelectronics, *Semiconductor Science and Technology*, 2018, vol. 33, no. 11, art. no. 113001.
[3] D. Dohy, J.R. Gavarri, Oxyde β-Ga2O3: Champ de Force, Dilatation Thermique, et Rigidité Anisotropes, *Journal of Solid State Chemistry*, 1983, vol. 49, no. 1, pp. 107–117.
[4] D.A. Bauman, D.Yu. Panov, V.A. Spiridonov, A.V. Kremleva, M.A. Odnoblyudov, A.V. Asach, V.A. Krylov, G.N. Isachenko, E.V. Tambulatova, V.E. Bougrov, A.E. Romanov, Measurements of heat capacity and thermal conductivity of β-Ga_2O_3 and β-$(Al_xGa_{1-x})_2O_3$ bulk crystals grown by the

Czochralski method, *Scientific and Technical Journal of Information Technologies, Mechanics and Optics*, 2021, vol. 21, no. 6, pp. 880–886.
[5] D.A. Bauman, A.I. Borodkin, A.A. Petrenko, D.I. Panov, A.V. Kremleva, V.A. Spiridonov, D.A. Zakgeim, M.V. Silnikov, M.A. Odnoblyudov, A.E. Romanov, V.E. Bougrov, On Improving the Radiation Resistance of Gallium Oxide for Space Applications, *Acta Astronautica*, 2021, vol. 180, pp. 125–129.
[6] S.I. Stepanov, V.I. Nikolaev, V.E. Bougrov, A.E. Romanov, Gallium Oxide: Properties and applications – a Review, *Reviews on Advanced Materials Science*, 2016, vol. 44, no. 1, pp. 63–86.
[7] H. Peelaers, J.B. Varley, J.S. Speck, C.G. Van De Walle, Structural and Electronic Properties of Ga_2O_3-Al_2O_3 Alloys, *Applied Physics Letters*, 2018, vol. 112, no. 24, art. no. 242101.
[8] D. Zakgeim, D. Bauman, D. Panov, V. Spiridonov, A. Kremleva, A. Smirnov, M. Odnoblyudov, A. Romanov, V. Bougrov, Growing of Bulk β-$(Al_xGa_{1-x})_2O_3$ Crystals from the Melt by Czochralski Method and Investigation of Their Structural and Optical Properties, *Applied Physics Express*, 2022, vol. 15, no. 2, art. no. 025501.
[9] G.T. Dang, T. Yasuoka, Y. Tagashira, T. Tadokoro, W. Theiss, T. Kawaharamura, Bandgap Engineering of α-$(Al_xGa_{1-x})_2O_3$ by a Mist Chemical Vapor Deposition Two-Chamber System and Verification of Vegard's Law, *Applied Physics Letters*, 2018, 113, no. 6, art. no. 062102.
[10] F. Zhang, K. Saito, T. Tanaka, M. Nishio, M. Arita, Q. Guo, Wide Bandgap Engineering of $(AlGa)_2O_3$ Films, *Applied Physics Letters*, 2015, vol. 105, no. 16, art. no. 162107.
[11] E.O. Filatova, A.S. Konashuk, Interpretation of the Changing the Band Gap of Al_2O_3 Depending on Its Crystalline Form: Connection with Different Local Symmetries, *The Journal of Physical Chemistry C*, 2015, vol. 119, no. 35, pp. 20755–20761.
[12] R.H. French, Electronic Band Structure of Al_2O_3, with Comparison to Alon and AIN, *Journal of the American Ceramic Society*, 1990, vol. 73, no. 3, pp. 477–489.
[13] J.B. Varley, First-Principles Calculations of Structural, Electrical, and Optical Properties of Ultra-Wide Bandgap $(Al_xGa_{1-x})_2O_3$ Alloys, *Journal of Materials Research*, 2021, vol. 36, no. 23, pp. 4790–4803.
[14] M. Mizuno, T. Yamada, T. Noguchi, The Liquidus Curve in the System Al_2O_3-Ga_2O_3 as Measured with a Solar Furnace, *Journal of the Ceramic Association, Japan*, 1975, vol. 83, no. 956, pp. 175–177.
[15] C. Remple, L.M. Barmore, J. Jesenovec, J.S. McCloy, M.D. McCluskey, Photoluminescence Spectroscopy of Cr^{3+} in β-Ga_2O_3 and $(Al_{0.1}Ga_{0.9})_2O_3$, *Journal of Vacuum Science & Technology A*, 2023, vol. 41, no. 2, art. no. 022702.
[16] A.F.M. A.U. Bhuiyan, Z. Feng, J.M. Johnson, H.L. Huang, J. Sarker, M. Zhu, M.R. Karim, B. Mazumder, J. Hwang, H. Zhao, Phase Transformation in MOCVD Growth of $(Al_xGa_{1-x})_2O_3$ Thin Films, *APL Materials*, 2020, vol. 8, no. 3, art. no. 031104.
[17] H. Li, Z. Wu, S. Wu, P. Tian, Z. Fang, $(Al_xGa_{1-x})_2O_3$-Based Materials: Growth, Properties, and Device Applications, *Journal of Alloys and Compounds*, 2023, vol. 960, art. no. 170671.
[18] D. Tahara, H. Nishinaka, S. Morimoto, M. Yoshimoto, Heteroepitaxial Growth of ε-$(Al_xGa_{1-x})_2O_3$ Alloy Films on *c*-Plane AlN Templates by Mist Chemical Vapor Deposition, *Applied Physics Letters*, 2018, vol. 112, no. 15, art. no. 152102.
[19] T. Oshima, T. Okuno, N. Arai, Y. Kobayashi, S. Fujita, β-$Al_{2x}Ga_{2-2x}O_3$ Thin Film Growth by Molecular Beam Epitaxy, *Japanese Journal of Applied Physics*, 2009, vol. 48, no. 7R, art. no. 070202.
[20] S.W. Kaun, F. Wu, J. S. Speck, *β*-$(Al_xGa_{1-x})_2O_3$/Ga_2O_3 (010) Heterostructures Grown on *β*-Ga_2O_3 (010) Substrates by Plasma-Assisted Molecular Beam Epitaxy, *Journal of Vacuum Science & Technology A: Vacuum, Surfaces, and Films*, 2015, vol. 33, no. 4, art. no. 041508.
[21] X. Xu, Z. Sheng, J. Shi, X. Chen, Y. He, W. Xu, X. Zhang, D. Chen, H. Qi, K.H.L. Zhang, Tuning the Bandgaps of $(Al_xGa_{1-x})_2O_3$ Alloyed Thin Films for High-Performance Solar-Blind Ultraviolet Fully Covered Photodetectors, *Advanced Optical Materials*, 2023, vol. 11, no. 13, art. no. 2300042.
[22] Z. Chen, M. Arita, K. Saito, T. Tanaka, Q. Guo, Epitaxial Growth of $(Al_xGa_{1-x})_2O_3$ Thin Films on Sapphire Substrates by Plasma Assisted Pulsed Laser Deposition, *AIP Advances*, 2021, vol. 11, no. 3, art. no. 035319.
[23] I. Milisavljevic, Y. Wu, Tb-Doped *β*-$(Al_xGa_{1-x})_2O_3$ Epitaxial Films on *c*-Sapphire Substrates Fabricated via a Spin-Coating Method, *Journal of Alloys and Compounds*, 2022, vol. 928, art. no. 167208.

[24] I. Milisavljevic, Y. Wu, Fabrication of Tunable Bandgap Epitaxial β-$(Al_xGa_{1-x})_2O_3$ Films Using a Spin-Coating Method, *International Journal of Applied Ceramic Technology*, 2023, vol. 20, no. 2, pp. 725–734.
[25] D.I. Panov, X. Zhang, V.A. Spiridonov, L.V. Azina, R.K. Nuryev, N.D. Prasolov, L.A. Sokura, D.A. Bauman, V.E. Bougrov, A.E. Romanov, Thin Films of Gallium Oxide Obtained by Spray-Pyrolysis: Method and Properties, *Materials Physics and Mechanics*, 2022, vol. 50, no. 1, pp. 107–117.